514 Rec'd PCT/PTO 13 MAR 2000

FORM PTO-1390 (REV 12-29-99) — U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
2971070US	09/508404

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FI98/00705	09 SEPTEMBER 1998	12 SEPTEMBER 1997

TITLE OF INVENTION
METHOD AND EQUIPMENT FOR ATTENTUATING SOUND IN A DUCT

APPLICANT(S) FOR DO/EO/US Seppo UOSUKAINEN, Vesa VALIMAKI, Kari KIRJAVAINEN, Jukka LEKKALA, and Hannu NYKANEN

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: International Preliminary Examination Report
    International Search Report
    Form PCT/IB/308
    Patent Data Entry Sheet

514 Rec'd PCT/PTO 13 MAR 2000

U.S. APPLICATION NO (if known, see 37 CFR 1.5) 09/508404	INTERNATIONAL APPLICATION NO. PCT/FI98/00705	ATTORNEY'S DOCKET NUMBER 2971070US

17. [X] The following fees are submitted:	CALCULATIONS PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :	
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $970.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $840.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $690.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) $670.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $96.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 970
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [X] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 130

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	8 - 20 =	0	X $18.00	$
Independent claims	2 - 3 =	0	X $78.00	$
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$

TOTAL OF ABOVE CALCULATIONS =	$ 1,100
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).	$
SUBTOTAL =	$ 1,100
Processing fee of $130.00 for furnishing the English translation later than [ ]20 [ ]30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$
TOTAL NATIONAL FEE =	$ 1,100
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$
TOTAL FEES ENCLOSED =	$ 1,100
Amount to be refunded:	$
charged:	$

a. [X] A check in the amount of $1,100. to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required by 37 CFR §1.16 and 1.17, or credit any overpayment to Deposit Account No. 25-0120. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:
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March 13, 2000

Benoit Castel
SIGNATURE:

Benoit Castel
NAME

35,041
REGISTRATION NUMBER

PATENTS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Seppo UOSUKAINEN et al.

Serial No. (unknown)

Filed herewith

METHOD AND EQUIPMENT FOR
ATTENUATING SOUND IN A DUCT

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents

Washington, D.C. 20231

Sir:

Prior to the first Official Action and calculation of the filing fee, please amend the above-identified application as follows:

IN THE CLAIMS:

Claim 4, line 1, cancel "or 3".

Add the following new claim:

--8. A method according to claim 3, characterized in that the control signals (q_1, q_2) of the elements the impact of the imaginary unit is determined by using an integrator.--

Respectfully submitted,

YOUNG & THOMPSON

By Benoît Castel

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March 13, 2000

METHOD AND EQUIPMENT FOR ATTENUATING SOUND IN A DUCT

The invention relates to a method for attenuating sound in a duct, the sound to be attenuated being detected in the method by means of a detector and the attenuation being performed by means of two successive actuator elements.

The invention also relates to an equipment for attenuating sound in a duct, the equipment comprising a detector for detecting the sound to be attenuated and two successive actuator elements for producing a sound attenuating counter-sound.

One of the methods presented for attenuating sound in ducts is a method known as the Swinbanks method, in which an attenuation sound is produced by means of two successive elements. Both elements produce a volume velocity of an equal amplitude, the volume velocities being, however, of opposite phases. In addition, to the element that is first in the direction of propagation of the sound to be attenuated is caused a delay proportional to the distance between the elements. A unidirectional, radiating element is thereby obtained, i.e. no acoustic feedback is caused to the detector measuring the sound to be attenuated. Instead, a signal is generated that only attenuates forward the sound of the sound source to be attenuated. To digitally implement inter-channel delay in different elements occupies, however, a great amount of signal processing resources, which means that the equipment to be used must have an extensive capacity and/or the processing time becomes inconveniently long.

An object of the present invention is to provide a method and an equipment that will allow the advantages of the above mentioned method to be obtained, avoiding, however, the above disadvantages.

A method of the invention is characterized in that sound is attenuated by means of two successive monopole elements in such a way that both elements function as a dipole approximation and also produce a monopole radiation needed, a dipole control signal being fed to both elements at a phase shift which is 180° between the two elements and a monopole control signal being fed to the elements cophasally.

Further, an equipment of the invention is characterized in that the actuator elements are monopole elements which are arranged to function as a dipole approximation and to also produce the monopole radiation needed and

that the equipment comprises means for feeding the dipole control signal to both elements at a phase shift which is 180° between the two elements and for feeding a monopole control signal to the elements cophasally.

An essential idea of the invention is that sound is attenuated by means of two successive monopole elements in such a way that both elements function as a dipole approximation and that, in an equal manner, they are also used for approximatively producingthe monopole radiation needed. The dipole control signal is fed to both elements at a phase shift which is 180° between the two elements. The monopole control signal is also fed to the same elements, only this time cophasally. Total volume velocities produced by both elements are combinations of the portions obtained from the monopole and dipole sources. An idea of a preferred embodiment is that control signals are specified by means of suitable control functions.

An advantage of the invention is that the equipment does not produce acoustic feedback between an actuator and the detector, because the equipment provides a unidirectional signal. In addition, the equipment is simple and in the control system of the equipment there is no inter-channel delay in the different elements, so when the equipment is used it is possible to apply simple algorithms and short processing times, while maintaining at the same time a good performance level. The use of control functions for specifying and correcting control signals allows an almost ideal system functionality to be obtained also at higher frequencies.

The term 'duct' is used in the present application to refer to a duct or a conduit, or the like, in which sound propagates substantially in only two directions at frequencies low enough.

The invention will be described in greater detail in the attached drawings, in which

Figure 1 is a schematic side view, in section, of an equipment of the invention;

Figure 2 is a diagram illustrating a control system of the invention;

Figure 3 illustrates a control function of a dipole part; and

Figure 4 illustrates a control function of a monopole part.

Figure 1 shows a duct 1. Sound appearing in the duct 1, caused by a sound source, is depicted with an arrow A. At a point x = -L is arranged a detector 2 which is used for detecting the sound caused by the sound source. In the direction of sound propagation, a first actuator element 3 is placed after

the detector 2 at a point x = -d/2 and a second actuator element 4 is placed after the first one at a point x = +d/2, the actuator elements 3 and 4 being at a distance d from each other. The actuator elements 3 and 4 are monopole elements, therefore they do not impede the flow of a medium in the duct 1. Figure 1 also schematically shows control means 5 for controlling actuator elements 3 and 4 on the basis of a signal received from the detector 2.

The first actuator element 3 produces a volume velocity q_1 and the second actuator element 4 produces a volume velocity q_2. Both actuator elements 3 and 4 function as a dipole approximation in such a way that a dipole control signal is fed to both elements 3 and 4 at a phase shift which is 180° between the two elements. In addition, a monopole control signal is fed to both elements 3 and 4, only this time cophasally. The total volume velocities q_1 and q_2 produced by the elements 3 and 4 are combinations of the portions obtained from monopole and dipole sources.

The volume velocity q_i describes the sound produced by the sound source at a point x = 0, the volume velocity q_i being proportional to the original sound pressure p_1 such that

$$q_1 = \frac{p_1 S}{\rho_0 c_0},$$

where S is the cross-sectional area of the duct, ρ_0 is the density of the medium in a static state and c_0 is the sound velocity in the medium.

The control signals of the actuator elements 3 and 4, i.e. the total volume velocities they produce, are

$$q_1 = \tfrac{1}{2}(1/jkd - \tfrac{1}{2})q_i, \; x = -d/2$$

and

$$q_2 = -\tfrac{1}{2}(1/jkd + \tfrac{1}{2})q_i, \; x = +d/2,$$

where

j is an imaginary unit;

k is a wave number = ω/c_0;

ω is an angular frequency;
c_0 is sound velocity in a medium; and
q_i is the original sound pressure to be attenuated, located at the point x = 0 and converted to a volume velocity quantity.

In the volume velocity expressions, the first parts relate to dipole radiation and the latter parts to monopole radiation.

The above described total volume velocities attenuate the sound produced by a sound source in the direction of propagation of the sound, and the actuator elements 3 and 4 do not radiate against the direction of sound of the sound source. At higher frequencies, however, the system does not function ideally, due to the approximative nature of the monopole and dipole radiation. Errors produced by the approximations can be compensated by means of suitable control functions. A dipole control function denoted by a quantity a and a monopole control function denoted by a quantity b allow the following total volume velocities to be obtained:

$$q_1 = \tfrac{1}{2}(a/jkd - b/2)q_i, \; x = -d/2,$$

and

$$q_2 = -\tfrac{1}{2}(a/jkd + b/2)q_i, \; x = +d/2.$$

The control system of the actuator elements 3 and 4 is shown as a diagram in Figure 2. In Figure 2 a quantity q_L denotes a signal measured by the detector 2, the signal being converted to a volume velocity quantity, and a delay τ_L denotes the time required for sound to propagate from the detector point x = -L to the actuator system centre x = 0, i.e. $\tau_L = L/c_0$, where c_0 denotes sound velocity in the medium. The delay in question can be estimated and implemented by means of an adaptive filter. In the embodiment shown in Figure 2 the imaginary unit j is replaced with an integrator, which allows the previously needed 90° phase shift and also the singularity of the control function at the frequency 0 to be avoided.

Errors produced by the approximations can be corrected for instance by applying the following dipole part control function

$$a = \frac{kd/2}{\sin(kd/2)}$$

and the following monopole part control function

$$b = \frac{1}{\cos(kd/2).}$$

A graph illustrating the dipole part control function a is shown in Figure 3 and a graph illustrating the monopole part control function b is shown in Figure 4. A quantity λ in Figures 3 and 4 denotes wave length. Monopole control is singular when $d = \lambda/2$. The continuous frequency area available is thus restricted to a frequency corresponding to the wave length in question.

The drawings and the related description are only meant to illustrate the inventive idea. The details of the invention may vary within the scope of the claims. An arrangement of the invention can thus also be used in a detector implementation. The most ideal function of an arrangement of the invention is obtained when the frequency is sufficiently low, ensuring that sound propagates only in a plane wave form only in the duct. The duct is most advantageously sufficiently long, so as to ensure that reflections from the duct ends do not affect the final result. In addition, the walls of the duct are most advantageously so hard that duct wall impedance need not to be taken into account. Further, the medium in the duct is most advantageously homogenous and motionless, sound velocity being equally high at every point of the duct and not dependent on the direction of sound propagation. Further, the medium is most advantageously so ideal that viscosity or thermal loss do not affect the final result.

CLAIMS

1. A method for attenuating sound in a duct, the sound to be attenuated being detected in the method by means of a detector (2) and the attenuation being performed by means of two successive actuator elements (3, 4), **characterized** in that sound is attenuated by means of two successive monopole elements (3, 4) in such a way that both elements (3, 4) function as a dipole approximation and also produce a monopole radiation needed, a dipole control signal being fed to both elements (3, 4) at a phase shift which is 180° between the two elements and a monopole control signal being fed to the elements (3, 4) cophasally.

2. A method according to claim 1, **characterized** in that the control signal of the first actuator element (3) is

$$q_1 = \tfrac{1}{2}(a/jkd - b/2)q_i,$$

and the control signal of the second actuator element (4) is

$$q_2 = -\tfrac{1}{2}(a/jkd + b/2)q_i,$$

where

j is an imaginary unit;

k is a wave number = ω/c_0;

ω is an angular frequency;

c_0 is sound velocity in a medium;

d is a distance between the actuator elements (3, 4);

q_i is the sound pressure to be attenuated, located at the centre of the actuator elements (3, 4), and converted to a volume velocity quantity;

a is a constant or a dipole part control function; and

b is a constant or a monopole part control function.

3. A method according to claim 2, **characterized** in that a is a dipole part control function and b is a monopole part function such that

$$a = \frac{kd/2}{\sin(kd/2)}$$

and

$$b = \frac{1}{\cos(kd/2)}.$$

4. A method according to claim 2 or 3, **characterized** in that in the control signals (q_1, q_2) of the elements the impact of the imaginary unit is determined by using an integrator.

5. An equipment for attenuating sound in a duct, the equipment comprising a detector (2) for detecting the sound to be attenuated and two successive actuator elements (3, 4) for producing a sound attenuating counter-sound, **characterized** in that the actuator elements (3, 4) are monopole elements which are arranged to function as a dipole approximation and to also produce a necessary monopole radiation and that the equipment comprises means for feeding a dipole control signal to both elements (3, 4) at a phase shift which is 180° between the two elements and for feeding a monopole control signal to the elements (3, 4) cophasally.

6. An equipment according to claim 5, **characterized** in that the control signal of the first actuator element (3) is

$$q_1 = \tfrac{1}{2}(a/jkd - b/2)q_i,$$

and the control signal of the second actuator element (4) is

$$q_2 = -\tfrac{1}{2}(a/jkd + b/2)q_i,$$

where

j is an imaginary unit;
k is a wave number = ω/c_0;
ω is an angular frequency;
c_0 is sound velocity in a medium;
d is a distance between the actuator elements (3, 4);
q_i is the sound pressure to be attenuated, located at the centre of the actuator elements (3, 4), and converted to a volume velocity quantity;
a is a constant or a dipole part control function; and
b is a constant or a monopole part control function.

7. An equipment according to claim 6, **characterized** in that a is a dipole part control function and b is a monopole part function such that

$$a = \frac{kd/2}{\sin(kd/2)}$$

and

$$b = \frac{1}{\cos(kd/2)}.$$

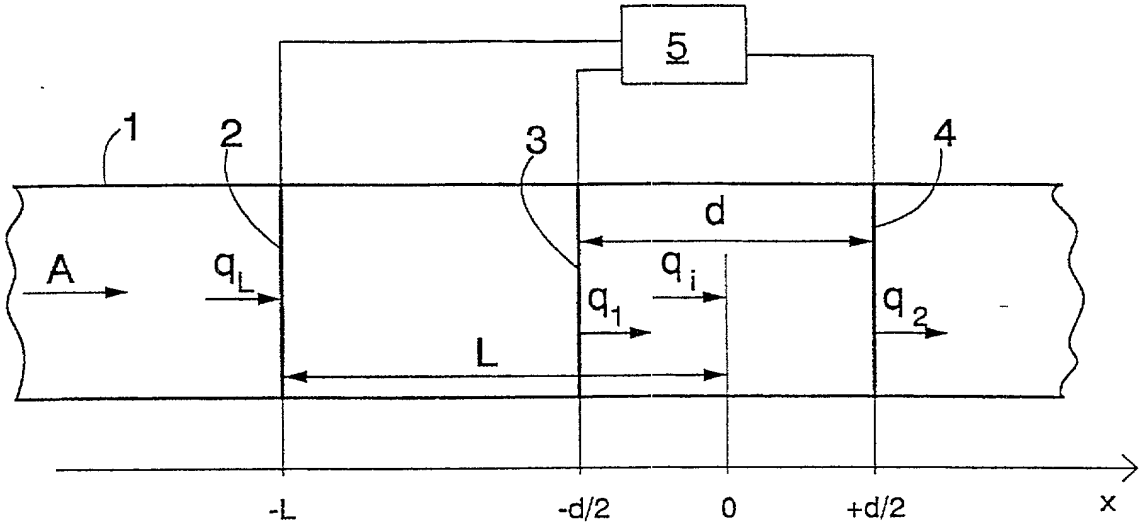

FIG. 1

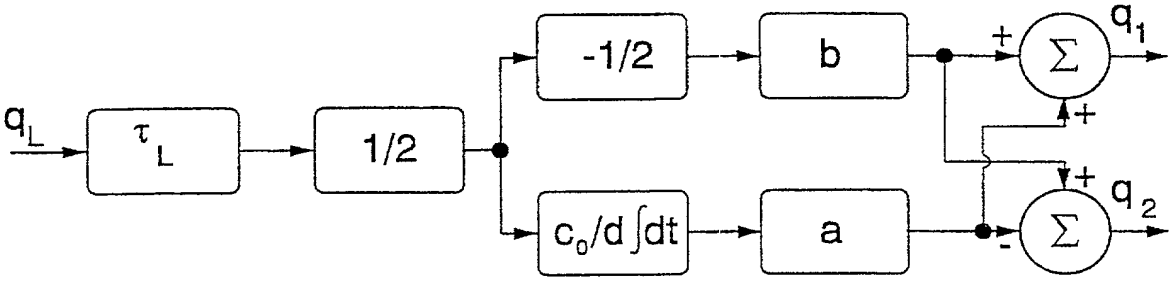

FIG. 2

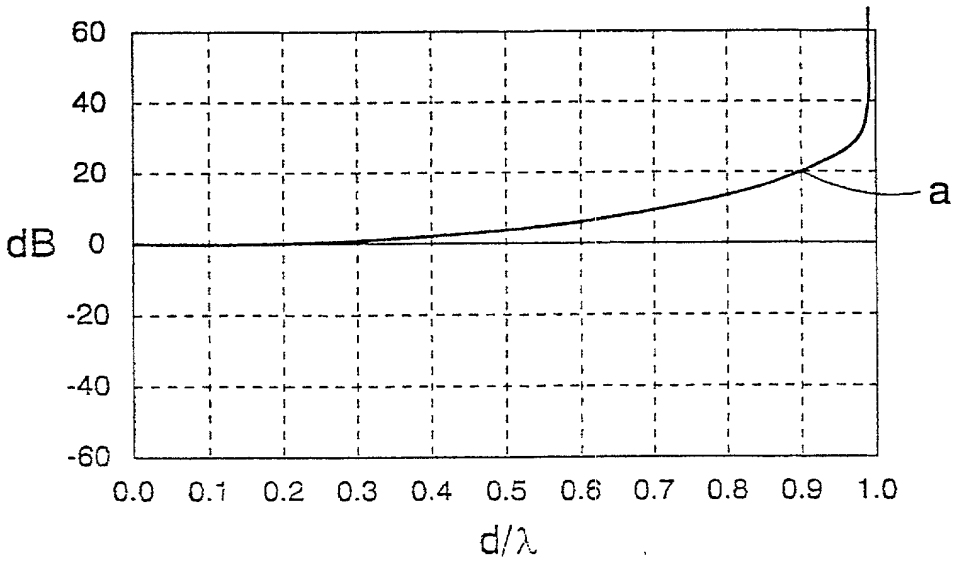

FIG. 3

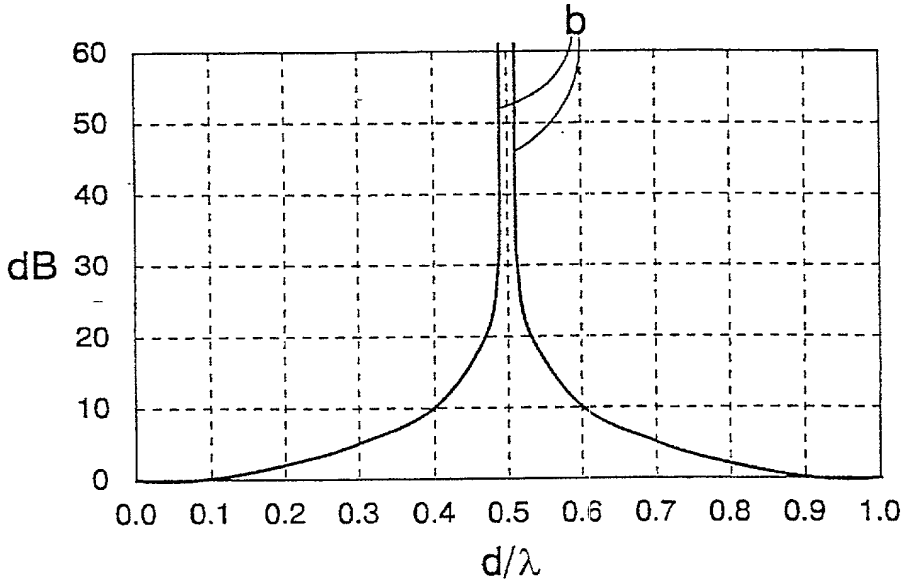

FIG. 4

Ref. _____

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Method and equipment for attenuating sound in a duct

the specification of which: *(check one)*

REGULAR OR DESIGN APPLICATION

[ ] is attached hereto.

[ ] was filed on _____ as application Serial No. _____ and was amended on _____ (if applicable).

PCT FILED APPLICATION ENTERING NATIONAL STAGE

[X] was described and claimed in International application No. PCT/FI98/00705 filed on 9 September 1998 and as amended on _____ (if any).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

PRIORITY CLAIM

I hereby claim foreign priority benefits under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

Country	Application Number	Date of Filing (day, month, year)	Priority Claimed
Finland	973677	12 September 1997	Yes

(Complete this part only if this is a continuing application.)

I hereby claim the benefit under 35 USC 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) (Filing Date) (Status--patented, pending, abandoned)

POWER OF ATTORNEY

The undersigned hereby authorizes the U.S. attorney or agent named herein to accept and follow instructions from ____ _____ as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorney or agent named herein will be so notified by the undersigned.

(6) As a named inventor, I hereby appoint the following attorney(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: **Robert J. PATCH, Reg. No. 17,355, Andrew J. PATCH, Reg. No. ~~32,925~~, Robert F. HARGEST, Reg. No. 25,590, Benoît CASTEL, Reg. No. 35,041, Eric JENSEN, Reg. No. 37,855, and Thomas W. PERKINS, Reg. No. 33,027**, c/o YOUNG & THOMPSON, Second Floor, 745 South 23rd Street, Arlington, Virginia 22202.

Address all telephone calls to Young & Thompson at 703/521-2297.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-0

Full name of sole or first inventor: Seppo UOSUKAINEN
(given name, family name)

Inventor's signature _____ FIX Date 7th Feb. 2000

Residence: Lehmustie 1 B, FIN-00780 ~~Helsinki~~, Finland Citizenship: Finnish

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2-0

Full name of second joint inventor, if any: Vesa VÄLIMÄKI
(given name, family name)

Inventor's signature _____ FIX Date 7 Feb. 2000

Residence: Mäenrinne 7 as. 3, FIN-02160 Espoo, Finland Citizenship: Finnish

Post Office Address: same as above

3-0

Full name of third joint inventor, if any: Kari KIRJAVAINEN
(given name, family name)

Inventor's signature _____ FIX Date 3.5.2000

Residence: Kivenlahdenkatu 11 A 4, FIN-02320 Espoo, Finland Citizenship: Finnish

Post Office Address: same as above

Full Name of Fourth, Joint Inventor	Inventor's Signature	Date
4-00 Jukka LEKKALA		12.4.2000
Residence: Liinaharjankatu 10, FIN-33730 Tampere, Finland FIN		**Citizenship** Finnish
Post Office Address: same as above		
Full Name of Fifth, Joint Inventor	**Inventor's Signature**	**Date**
5-00 Hannu NYKÄNEN		12.4.2000
Residence: Timpurinkatu 3, FIN-33720 Tampere, Finland FIN		**Citizenship** Finnish
Post Office Address: same as above		
Full Name of Sixth, Joint Inventor	**Inventor's Signature**	**Date**
Residence:		**Citizenship**
Post Office Address:		
Full Name of Seventh, Joint Inventor	**Inventor's Signature**	**Date**
Residence:		**Citizenship**
Post Office Address:		